Interaction Region Issues

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for the

EIC User Group Meeting

Jan. 6-9, 2016

Outline

- **Brief Introduction**
  – Beam parameters
- **Detector**
  – Magnetic field
  – Very low angle detectors
- **Backgrounds**
  – Synchrotron Radiation backgrounds
  – Beam-Gas-Bremsstrahlung
  – Luminosity backgrounds
- **Wake-field and Higher-Order-Mode Power**
  – Smooth beam pipes
- **Summary**
- **Conclusion**

Accelerator

- **The EIC accelerator design(s) have large beam energy range(s) for both beams**
  - 5-20 GeV for e-
  - 20-250 GeV for the ions
- **This flexibility must be carefully observed when designing IR details**
  - SR for the electron beam is a good example

Electron IR Parameters

JLEIC design parameters

- **Electron beam**
  - Energy range: 3-10 GeV
  - Current (5/10 GeV): 3/0.7 A
  - Beam-stay-clear: 12 beam sigmas
  - Emittance ($\varepsilon_x/\varepsilon_y$) (5 GeV): (14/2.8) nm-rad
  - Emittance ($\varepsilon_x/\varepsilon_y$) (10 GeV): (56/11) nm-rad
  - Betas
    - $\beta_x^* = 10$ cm　　β_x max = 300 m
    - $\beta_y^* = 2$ cm　　β_y max = 325 m
- **Final focus magnets**

Name	Z of face	L (m)	k	G (10 GeV-T/m)
QFF1	2.4	0.7	-1.3163	-43.906
QFF2	3.2	0.7	1.3644	45.511
QFFL	4.4	0.5	-0.4905	-16.362

Ion IR Parameters

- **Proton/ion beam**
  - Energy range 20-100 GeV
  - Beam-stay-clear 12 beam sigmas
  - Emittance ($\varepsilon_x/\varepsilon_y$) (60 GeV) (5.5/1.1) nm-rad
  - Betas
    - β_x^* = 10 cm β_x max = 2195 m
    - β_y^* = 2 cm β_y max = 2580 m
- **Final focus magnets**

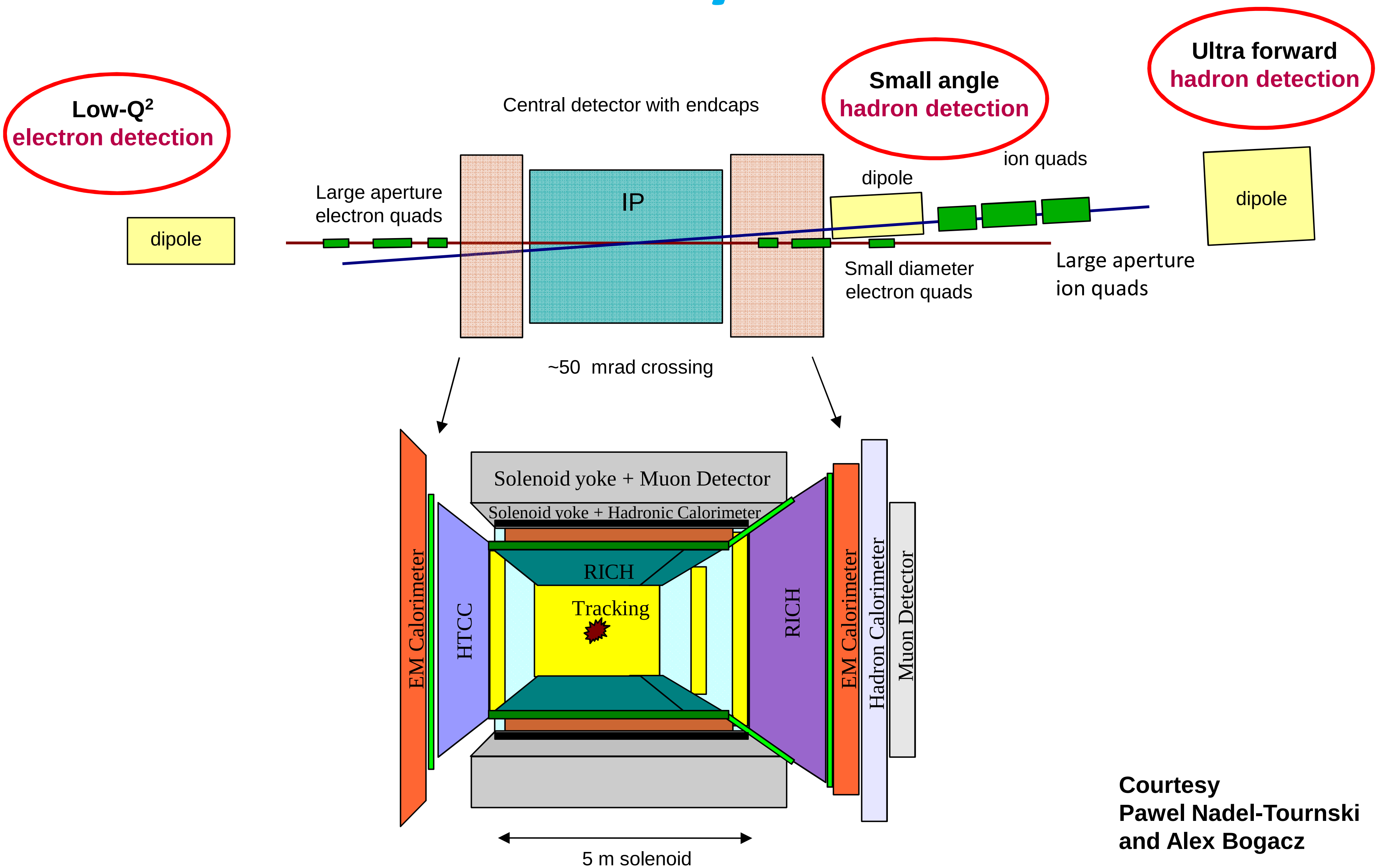
Name	Z of face	L (m)	k	G (60 GeV)
QFF1	7.0	1.0	-0.3576	-71.570
QFF2	9.0	1.0	0.3192	63.884
QFFL	11.0	1.0	-0.2000	-40.02

The Detector

Echo of some of the points made by the excellent presentations of E. C. Aschenauer and U. Wienands

- **Standard Features**
  - Central Solenoidal field (1.5-3 T)
  - As much SA as possible
  - Small SA occlusion for the final focus magnets
- **Unique Features**
  - Far forward angle detectors
  - Aiming for 0 deg SA detection in the downstream beamline for both beams
    - Ion beam
    - Electron beam

IR Layout



Courtesy
Pawel Nadel-Tournski
and Alex Bogacz

Electron Beam Forward Detectors

- The electron beam forward detectors will have backgrounds from SR and luminosity related processes (radiative Bhabhas, etc.) as well as nearby beam-gas interactions

- The electron beam will also produce HOM (wake-field) energy that can affect very small angle detectors that want to be inside the beam pipe

Ion Beam Forward Detectors

- The ion beam will have similar beam (and perhaps luminosity) related backgrounds but no SR
- The ion beam has a very short beam bunch (by ion beam standards) and this will increase the tendency for HOM and wake-field effects
- However, the beam γ is still low (~30-250) which reduces wake-field effects
- But remember that a few tenths of Watts of HOM power can still melt and burn up detectors if they are not cooled (more on this)

SR backgrounds

- We need to check background rates for various machine designs
- The large JLEIC flexibility (5-10 GeV for electrons) makes building a single IR beam pipe challenging
- The 5 GeV e- design has the highest beam current
- The 10 GeV design has the highest SR photon energies and the largest beam emittance

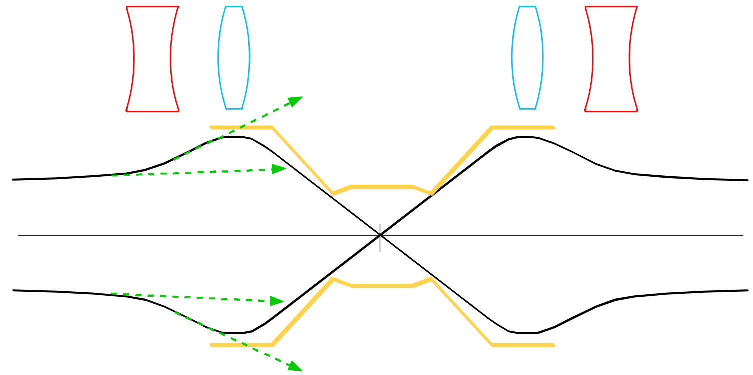
Final Focus Sources

Generic Final Focus optics

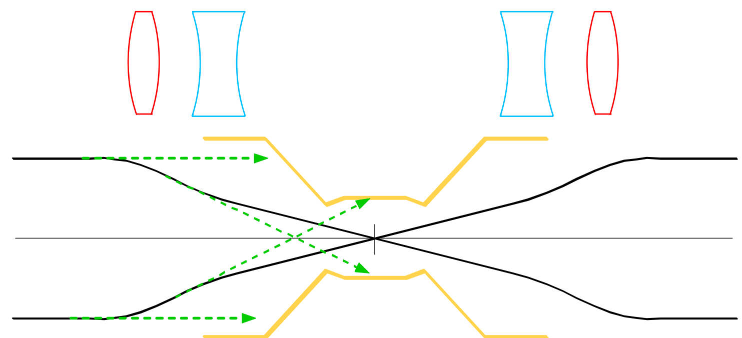
The X focusing magnets are outside of the Y focusing magnets

For flat beams the magnets do not fight each other

Round beam optics have much stronger magnets making them much larger SR sources

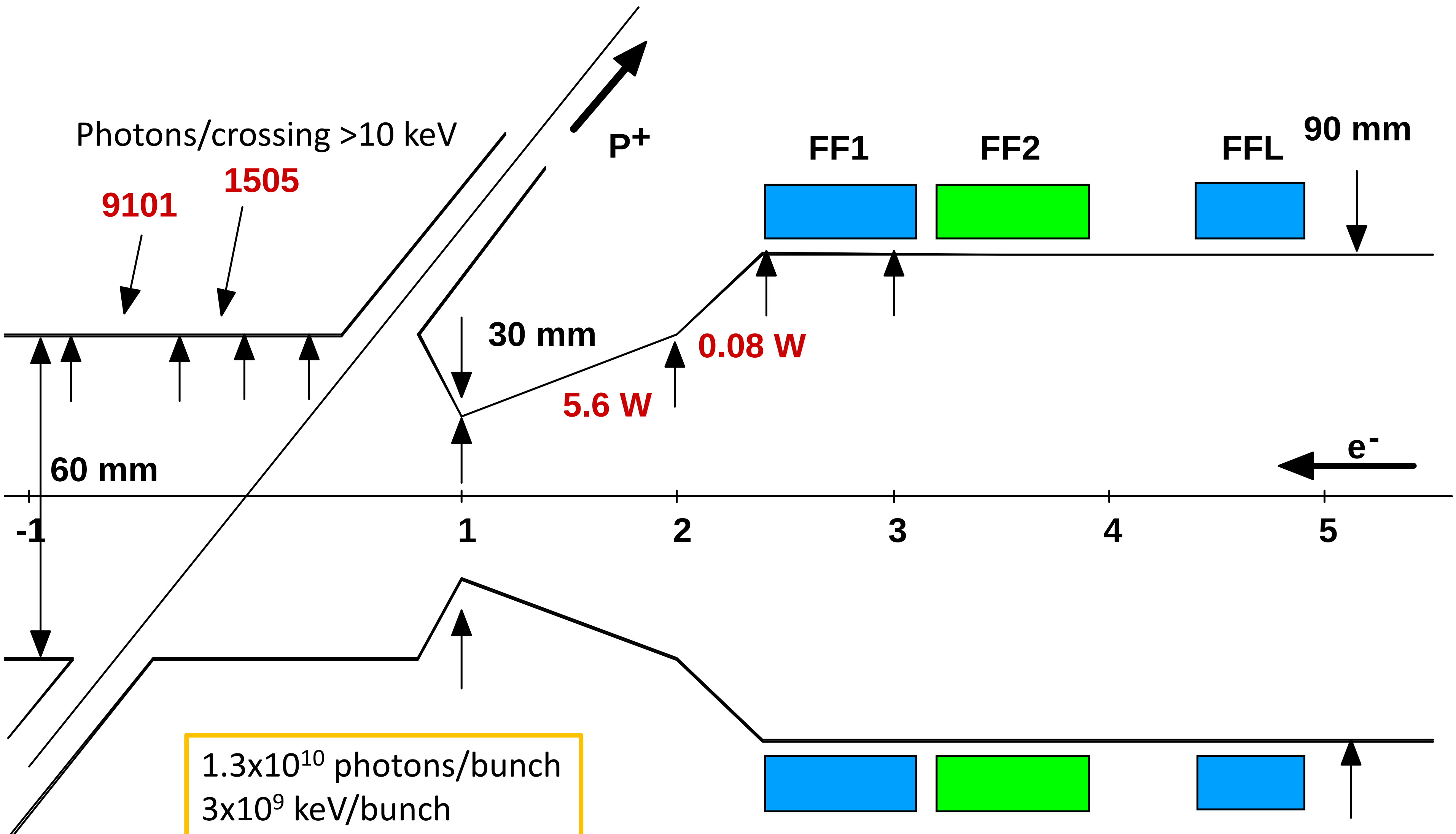


Vertical beam focusing
(side view)



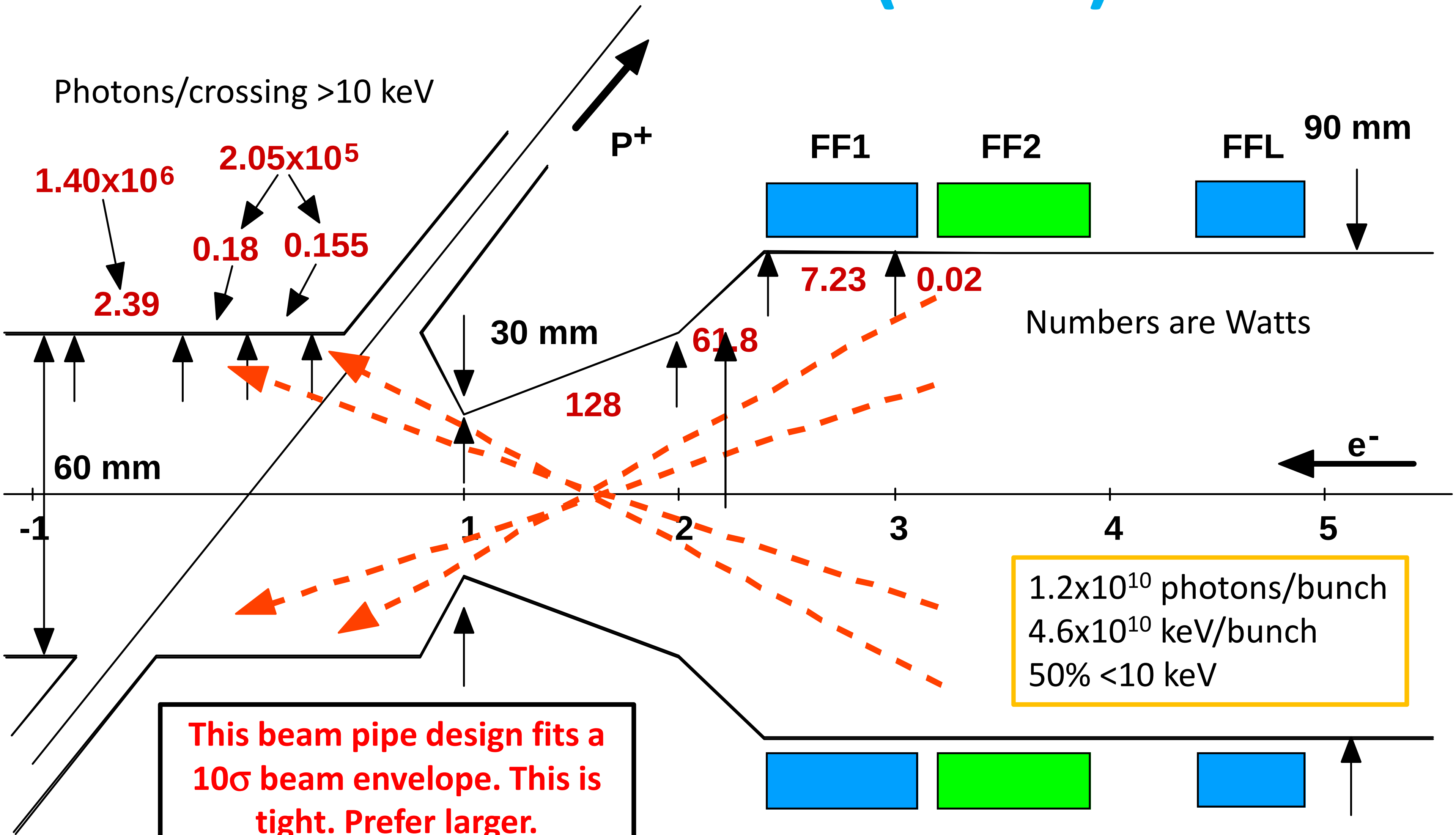
Horizontal beam focusing
(plan view)

SR for 5 GeV (3 A)



1.3x10^{10} photons/bunch
3x10^{9} keV/bunch
90% <10 keV

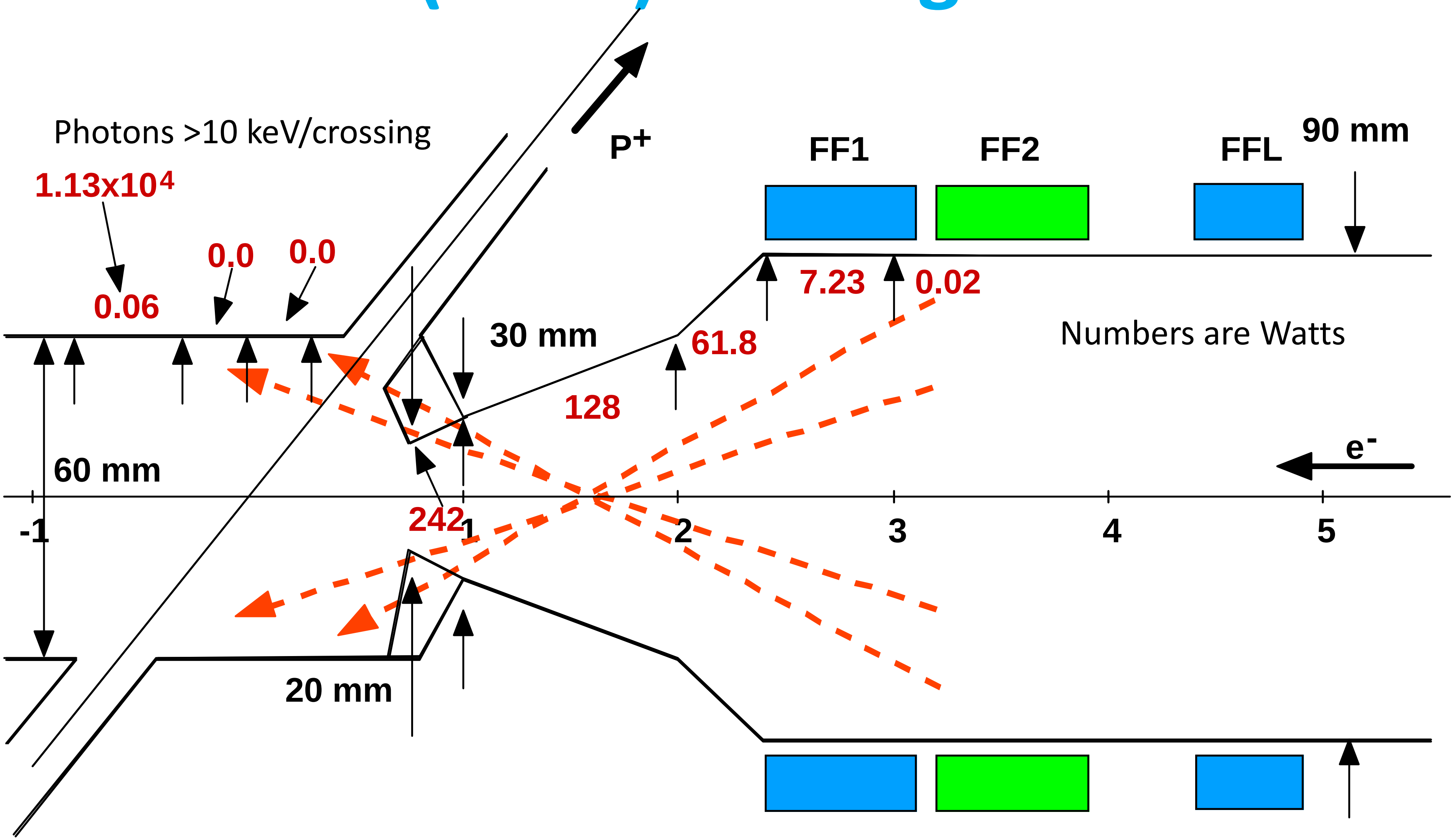
SR for 10 GeV (0.7 A)



1.2×10^{10} photons/bunch
4.6×10^{10} keV/bunch
50% <10 keV

This beam pipe design fits a 10σ beam envelope. This is tight. Prefer larger.

10 GeV (0.7 A) with tighter mask



SR results

- **Difficult to get an IR beam pipe much smaller than a 3cm radius in X. Y is better.**
  - Need to see how many photons penetrate the beam pipe and make a hit in the first inner detector
- **Need to know how long the central pipe needs to be**
  - Shorter pipes are easier to shield
- **For the 10 GeV case the masking is tight**
  - This probably makes a problem for BGB backgrounds (next topic)

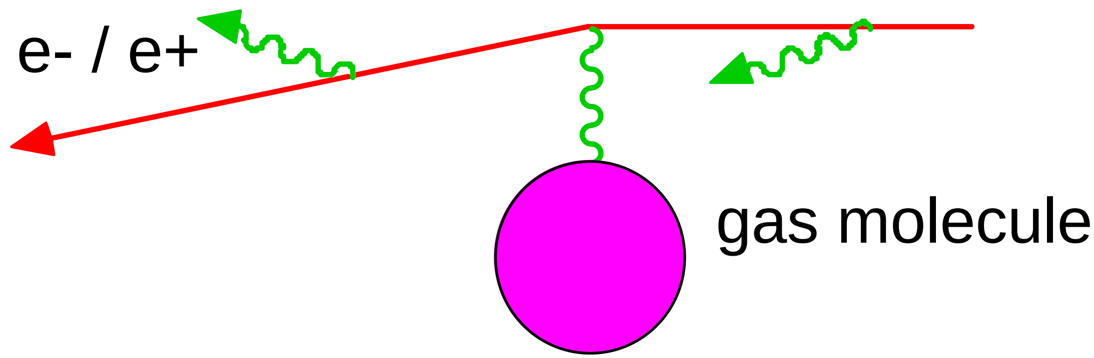
BGB, Coulomb, etc.

- **There are several processes that enter here:**
  - Electron – gas molecule **inelastic** collision (BGB)
  - Electron – gas molecule **elastic** collision (Coulomb)
  - Ion – gas molecule nuclear collision (Inelastic)
  - Ion – gas molecule elastic collision (Coulomb)
- **The elastic collisions tend to produce a halo (or tail) distribution around the beam**
  - Need to track these collisions around a much larger part of the ring (perhaps the entire ring)

Electron – gas molecule

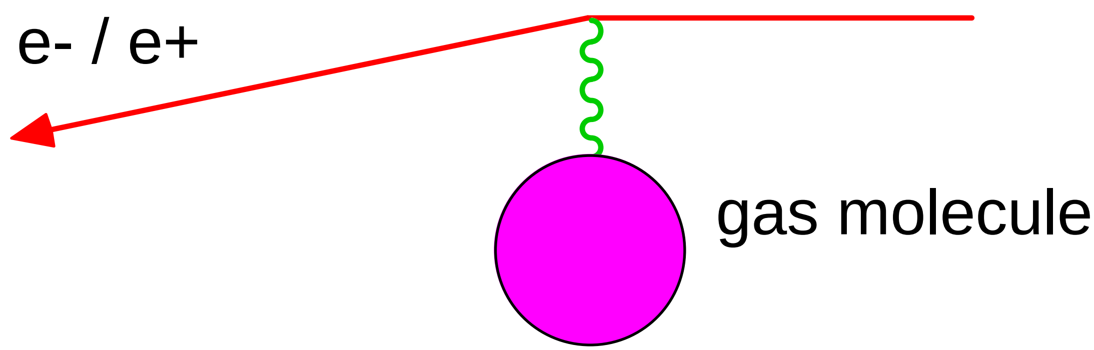
BGB – Electron-gas **inelastic** collision

Result is a high energy gamma and a very off-energy electron beam particle



Coulomb – Electron-gas **elastic** collision

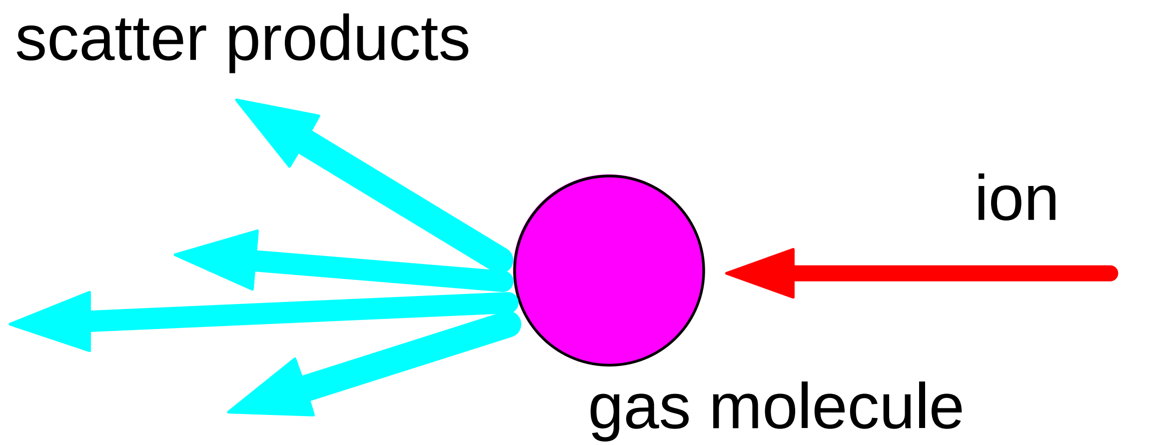
Result is an on-energy electron beam particle but with a large scattering angle



Ion – gas molecule

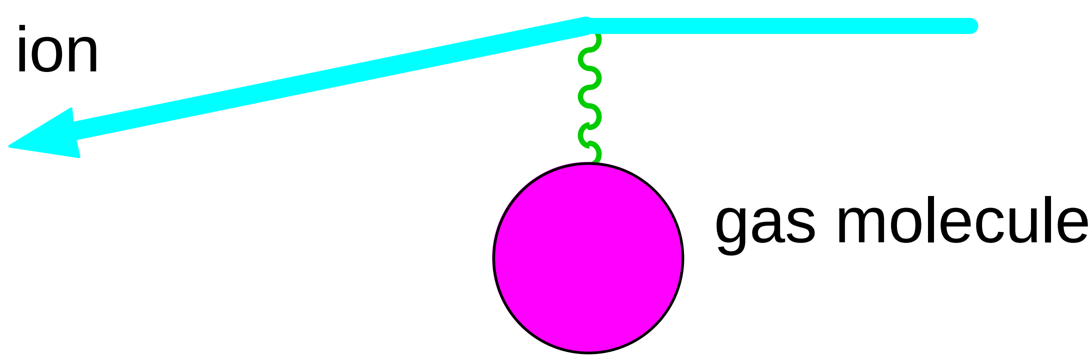
Ion-gas nuclear collision

Result is a mess with probably all particles lost locally



Ion-gas **elastic** collision

Result is an on-energy ion beam particle but with a large scattering angle



More on BGB, etc.

- The nuclear collisions between ion and gas molecule will most likely vanish from the machine close to the location of the collision point

- The elastic ion – molecule collision will probably also produce a halo around the ion beam but this we should be able to collimate away

- We will need to study where the best locations for collimation are while minimizing scattering from the collimators that end up making new background sources

Luminosity backgrounds

- **Luminosity backgrounds include:**
  - ePbremsstrahlung (also lumi signal and low Q^2 data)
  - Off-energy electron beam particles from above (also low Q^2 data)
    - > MHz rate
  - eP → eeeP (two photon electron pair production)
    - The very low energy e+e- pair curl up in the detector field and make multiple hits in the vertex tracker
- **These will need to be checked to make sure they are under control or are not an issue**

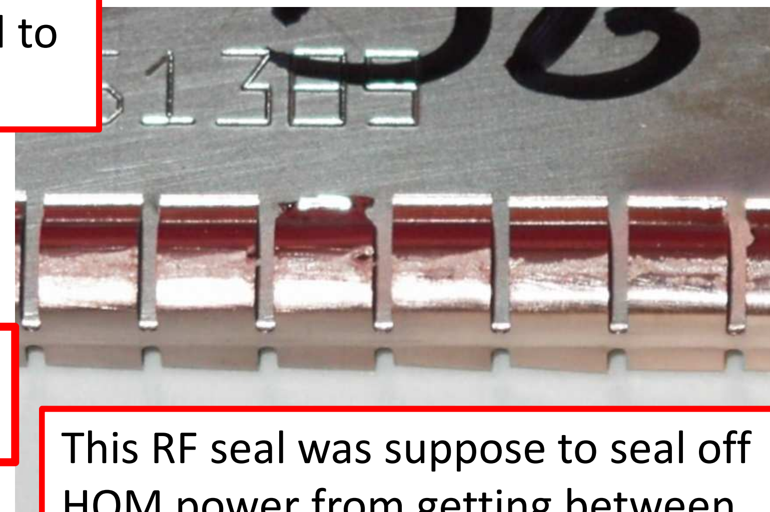
Wake-fields and HOMs

- **HOM power and wake fields mostly come from the electron beam and travel up (and down) the electron beam pipe *and* the proton beam pipe**
  - It comes from the shared IP beam pipe

- **The proton beam does not generate nearly as much HOM power as the electron beam mainly because of the low gamma**
  - Still needs to be checked for beam pipes that have cavities. **Low power can still melt vacuum elements**.

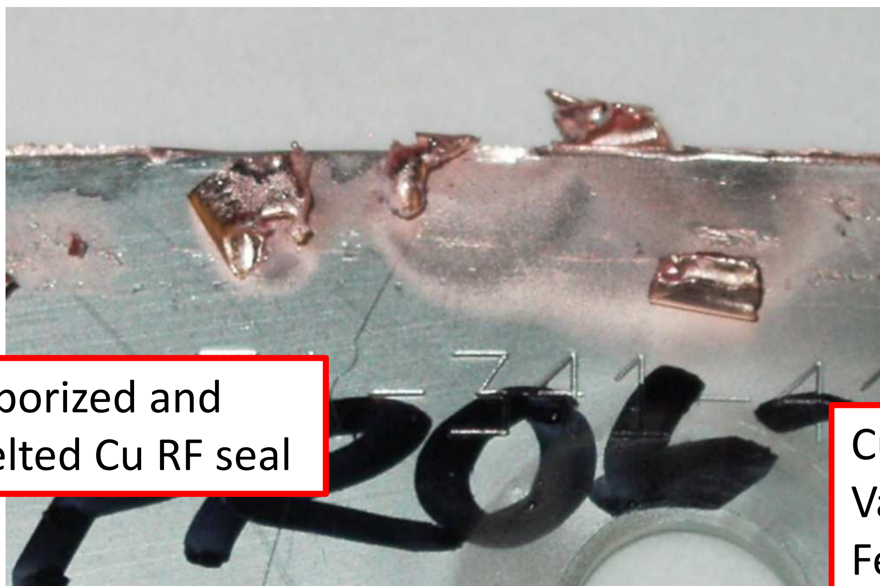
We estimate that a few Watts did this

The seal frame was SS and was bolted to **water cooled Cu**



HER beam
1.5-1.8 A

This RF seal was suppose to seal off HOM power from getting between two vacuum flanges that had some amount of internal flex



Vaporized and melted Cu RF seal

3/8" SS washer melted

Cu melts at 1357
Vaporizes at 2840
Fe melts at 1808

Summary

- There are several background sources that need to be studied
- We need to make sure all of the sources are under control
- Backgrounds can change as the IR design evolves
- Background sources need to be continually checked and rechecked

Conclusions

- SR for the JLEIC IR looks under control but needs further study
- BGB backgrounds need to be checked
- Luminosity backgrounds need be calculated
- HOM effects need to be estimated
- Low and zero angle detector backgrounds need to be calculated

- There is always lots to do…